CHAPTER 1
INTRODUCTION

1-1. Purpose. The purpose of this manual is to outline techniques and procedures of rock reinforcement for underground and surface structures in civil engineering works. Design procedures and examples of successful installations are presented for guidance in the design and construction of rock reinforcement systems.

1-2. Applicability. This manual provides guidance to all elements of the Corps of Engineers responsible for the design and construction of rock reinforcement systems.

1-3. References.

a. Works Cited. Standard references pertaining to this manual are listed in Appendix F. Superior numbers are used in the text to identify similarly numbered items in Appendix F.

b. Bibliography. Additional sources of information for supplementary reading are listed in Appendix G.

1-4. Terminology. The following definitions are presented as terminology that is essential to the use of this manual.

a. Rock Reinforcement. The placement of rock bolts, untensioned rock dowels, prestressed rock anchors, or wire tendons in a rock mass to reinforce and mobilize the rock's natural competency to support itself.

b. Rock Support. The placement of supports such as wood sets, steel sets, or reinforced concrete linings to provide resistance to inward movement of rock toward the excavation.

c. Rock Bolt. A tensioned reinforcement element consisting of a rod, a mechanical or grouted anchorage, and a plate and nut for tensioning or for retaining tension applied by direct pull or by torquing.

d. Prestressed Rock Anchor or Tendon. A tensioned reinforcing element, generally of higher capacity than a rock bolt, consisting of a high strength steel tendon (made up of one or more wires, strands or bars) fitted with a stressing anchorage at one end and a means permitting force transfer to the grout and rock at the other end.

e. Rock Dowel. An untensioned reinforcement element consisting of a rod embedded in a mortar or grout filled hole.

f. Element. General term for rock bolts, tendons, and rock anchors.

g. Pattern Reinforcement. The installation of reinforcement elements in a regular pattern over the excavation surface.

h. Spot Reinforcement. The installation of reinforcement elements in localized areas of potential instability or weakness as determined during excavation. This spot reinforcement may be in addition to pattern bolting or structural support.

1-5. Concept of Rock Reinforcement.

a. There are numerous variations of the concept of rock reinforcement. Each variation is usually derived from a particular theory that is used to calculate required reinforcement. The central concept found in all variations is that of rock mass strengthening. In other words, reinforcement is used to enhance the ability of the rock to be self-supporting. Rock masses are quite strong if progressive failure along planes of low strength is prevented. It is the purpose of reinforcement to prevent this failure, thereby allowing the rock to support itself with its inherent strength.

b. Rock in situ may be thought of as a complex structure of discrete blocks or fragments with near perfect interlocking of these blocks and fragments (EM 1110-1-1801[1]). In most civil engineering applications the material strength of the intact rock between discontinuities is high relative to the expected stresses. For this reason, deformation of the rock is generally controlled by the discontinuities. These discontinuities may be joints, bedding plane joints, foliation surfaces, shear zones, or faults.

c. Progressive deformation and relaxation may result in the collapse of a portion of the rock structure when shear stresses along discontinuities are only a fraction of the in situ rock mass shear strength. In jointed rock masses, numerous factors determine the nature and extent of the rock mass deformation. These include the following:

(1) The strength, deformability, orientation, and frequency of discontinuities.

(2) The size, shape, and orientation of the excavation with respect to the discontinuities.

(3) Method of excavation.

(4) The state of stress in the rock mass surrounding the excavation.

(5) Strength of the intact rock.

d. Rock reinforcement prevents or limits the deformation and dilation of the rock that may lead to collapse. The strength of the rock is maintained by the reinforcement. A more specific explanation of rock reinforcement is that it provides tensile, shear, and/or frictional strength across discontinuities. In this respect it is similar to diagonal tension reinforcement in reinforced concrete structures. The primary reason for the success of rock reinforcement is the immediate restraint which reduces rock deformation thus greatly enhancing the possibility of early stabilization following excavation. The shear strength of the discontinuities will always be less after slippage or separation has taken place. For this reason the reinforcement should be installed as soon as possible after the excavation is made. As is the case in the design of any structure, the usual parameters are determined not only by available design procedures but also by experience and appropriate empirical rules. For rock reinforcement these parameters include element spacing, size, prestress forces, and lengths.

e. The advancing state-of-the-art of rock reinforcement has now reached the point that it is always considered as an alternative or partial alternative to direct structural support of rock excavations. In its various forms, reinforcement is in common use on projects with open cuts, portals, tunnels, shafts, and large chambers as well as for stabilizing existing slopes and strengthening weak foundation rock such as the passive wedge areas immediately downstream from the toes of concrete dams. The savings that may be realized by using rock reinforcement rather than internal structural support for underground openings make the consideration of reinforcement a necessity in the design for rock stabilization of these types of excavations.

f. To provide positive, corrosion resistant reinforcement, all reinforcing elements must be permanently bonded to the rock by surrounding the elements with grout, mortar, or resins.